Rainbow Trout Abundance in the Kisaralik River, Yukon Delta National Wildlife Refuge, Alaska, 1997

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Abstract

The abundance of rainbow trout *Oncorhynchus mykiss* in a 70-kilometer study section of the Kisaralik River was estimated using mark-recapture techniques during July and August of 1997. A total of 1,115 rainbow trout were captured using hook and line gear, tagged with numbered Floy® anchor tags, and released at point of capture. During the second event (recapture), 1,146 fish were captured and 103 were found to have tags or secondary marks. The estimated abundance of fish of length 300-350 mm was 1,873, with standard error 735, and the abundance of fish of length 350mm or greater was estimated as 7,390, with standard error 693. The total abundance of fish of length 300 mm or greater was 9,263, with standard error 1,010. The abundance of fish less than 300 mm in length was not estimated.

Introduction

Rainbow trout *Oncorhynchus mykiss* populations of southwest Alaska support both sport and subsistence fisheries and attract people from all over the world (Alaska Department of Fish and Game 1990). The Kisaralik River is located on the Yukon Delta National Wildlife Refuge (Refuge) at the northern and western most extension of rainbow trout distribution in North America. This river has remained relatively unknown to anglers outside of the area, with most recreational angler use occurring on well-known rivers such as the Goodnews and the Kanektok rivers on the Togiak National Wildlife Refuge. Anglers access the river both by rafts and motor boats. The estimated float use on the Kisaralik River in 1982 was 7 parties and 24 persons. Use subsequently increased to 10 parties in 1990, 20 in 1995, and 32 in 1996 (U. S. Fish and Wildlife Service 1997). The recent increase in angler use of the Kisaralik River is likely attributable to several factors. First, sport-fishing use has increased statewide and expanded westward. Kisaralik Lake, the headwater of Kisaralik River, is accessible from both Dillingham and Bethel, where the number of air taxi operators with floatplanes has increased in recent years. Motor boat use in the lower river by sport and subsistence users has grown along with the local population. Bethel, a regional transportation hub, has grown from 3,681 in 1984 to just under 6,000 residents in 2003 (Alaska Department of Labor 2004, U.S. Fish and Wildlife Service 1988).

According to the Alaska Department of Fish and Game's Statewide Harvest Survey, angling effort on the Kisaralik River increased during 1994, and the river was listed in the statewide angler survey for the first time (Howe et al. 1995). The survey estimated angler effort to be 1,463 angler-days. Estimated harvests were 117 Dolly Varden *Salvelinus malma*, 124 rainbow trout, 69 Arctic grayling *Thymalus arcticus*, 148 Chinook salmon *O. tshawytscha*, 72 coho salmon *O. kitsutch*, 0 sockeye salmon *O. nerka*, 98 pink salmon *O. gorbuscha*, and 58 chum salmon *O. keta*. By comparison, anglers expended approximately 6,505 angler-days on the Kanektok River in 1994, up from 600 angler-days in 1980 (Wagner 1991), when angling pressure first started to increase on that river. Survey results for 2000 estimated the Kisaralik

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River use at 373 anglers, 492 trips, and 2,084 angler-days (Walker et al. 2003). These anglers harvested 10 Chinook and 199 coho salmon, 367 Dolly Varden 47 rainbow trout, and 29 Arctic grayling. Harvests of Kisaralik River fish by subsistence fishers is unknown and does not show up in the estimates of use, catch, and harvest reported in the Statewide Harvest Survey. This user group would not normally receive a survey questionnaire unless they purchase an Alaska sport-fishing license.

Increasing angling pressure and harvest on the rainbow trout population is of management concern. Rainbow trout at this northern latitude grow slowly and mature late at approximately age 6 (Wagner 1991, Adams 1999), two factors that increase vulnerability to over-exploitation. Population declines, measured by abundance and size structure alterations or declines in catch have prompted the Alaska Board of Fisheries to enact seasonal gear and harvest restrictions in other systems in southwestern Alaska. The Alaska Department of Fish and Game (Department) established policies that emphasize conservative wild stock management and provide for a diversity of angling opportunities. The objectives of these policies are to preserve the historic size and age structure of rainbow trout stocks in southwestern Alaska (Minard 1990).

The Alaska National Interest Lands Conservation Act (ANILCA) mandates that the Refuge shall be managed to “conserve fish and wildlife populations and their natural diversity” and “provide subsistence opportunities for local residents”. Compliance with ANILCA mandates, however, is not ensured when reliable data on fish populations are not available. The Refuge Fishery Management Plan (U. S. Fish and Wildlife Service 1992) management strategy is to maintain, to the maximum extent possible, the natural diversity of fish populations and habitats throughout the Refuge. One of the primary objectives is to determine the population dynamics and harvest levels of resident fish in seven Refuge watersheds, including Kisaralik River rainbow trout.

Prior to this study rainbow trout samples collected from surveys of the Kisaralik River were minimal with less than 50 fish sampled in 1976 (Alt 1977) and 1986 (Faurot and Jones 1992) These samples were not large enough to characterize the population. The objectives of this study were to 1) estimate rainbow trout abundance between river kilometer 44 and 120 such that the estimate is within 10% of the true abundance 90% of the time, and 2) estimate rainbow trout size composition.

Study Area

The Refuge experiences a sub-arctic climate with extreme temperature minima and maxima; temperatures range from summer highs near 15°C to average winter lows near -12°C (Alt 1977). Average yearly precipitation is approximately 50 cm, with the majority of it falling between June and October. Local rivers typically become ice free in early May and freeze-up occurs in late November.

Originating in the Kilbuk mountains, the Kisaralik River drains approximately 2,771 km^2 (Figure 1). The river flows northwesterly from Kisaralik Lake, elevation 480 m (1,577 feet), for approximately 26 km and drops 116 m (377 feet) before entering the Refuge. From the Refuge boundary to Golden Gate Falls, the river travels 40 km and drops an average of 4 m/km. From Golden Gate Falls to the lower Refuge boundary, the river travels 70 km and drops an average of 2.8 m/km. Swift water over a boulder and bedrock substrate characterizes the river down to Golden Gate Falls, a non-barrier to salmon.

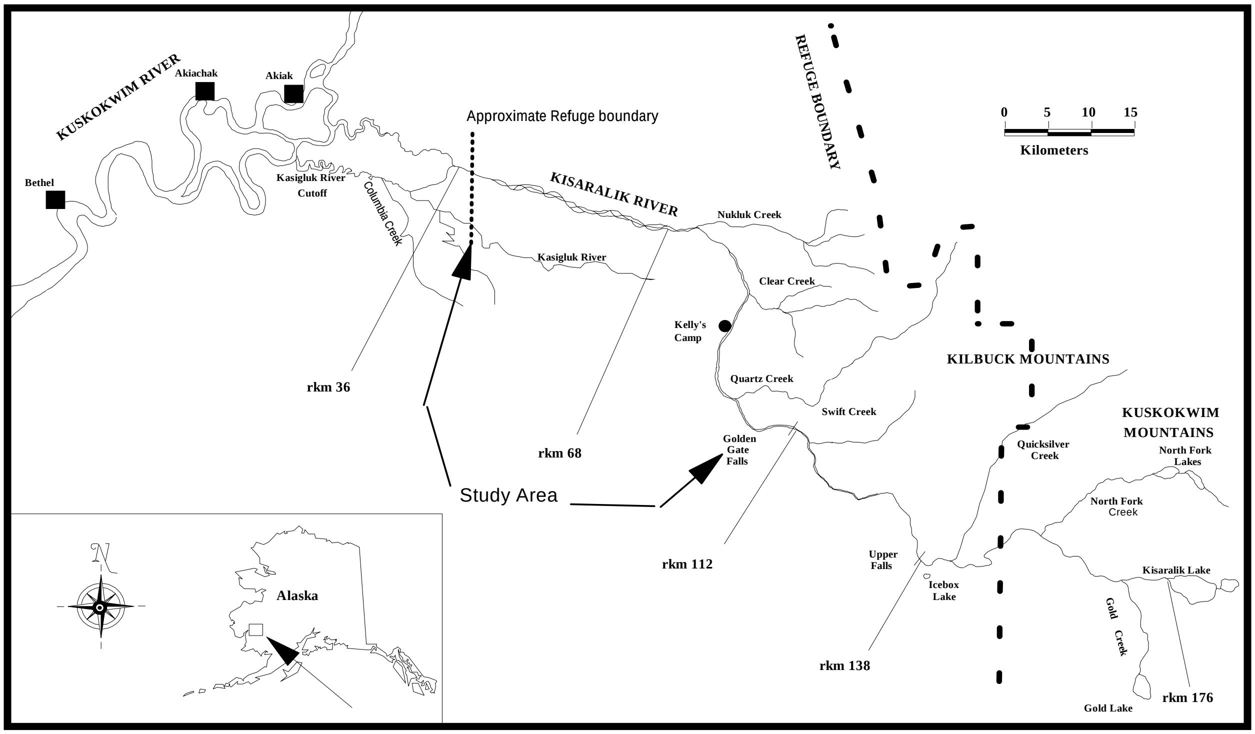

FIGURE 1.–Kisaralik River study area, Yukon Delta National Wildlife Refuge.

The river emerges from the canyon below Golden Gate Falls into a braided channel with logjams and overhanging willow and alder banks. Substrates in the middle section consist primarily of gravel, rubble, and sections of bedrock. In the lower river section, the channel is deeper, approximately 36 m in width, and lined with either mud or fine sand (Alt 1977). Turbid water conditions from eroding tundra banks characterize the lower section during the summer. The river empties into the Kuskokwim River near the village of Akiak after flowing 176 km from its headwaters. A recent change in channel configuration has allowed the river in certain years to flow into the Kasigluk River, reducing flow in the lower river.

Methods

Fish Capture

A mark-recapture study of the abundance and size composition of rainbow trout in a 70 km section of the Kisaralik River between Golden Gate Falls and the Refuge boundary (Figure 1) was conducted in 1997. The marking event occurred from July 8-19, 1997. One tagging crew of two anglers floated the study area in a raft, starting on July 8th and finishing on July 12th. A second tagging crew of nine anglers in four rafts marked fish from July 11 to July 19. Anglers fished primarily from the riverbanks. However, some fishing occurred as teams floated between river sections, passing anglers on the banks. Approximately one angler day was expended for every 0.8 km. The river was thoroughly sampled with all habitat types covered throughout the 70 km study area. Attempts were made to distribute fishing effort in proportion to fish abundance, with more effort being expended in areas where fish appeared to be concentrated.

The recapture event occurred August 6-16, 1997, starting nearly 30 days after the beginning of the marking event. Eight anglers floated the entire study area. Two additional anglers joined the crew on the last two days of this period, accessing the lower portion of the study area using a motor boat. Methods of fishing were similar to those used during the marking event.

All fish were captured using hook and line gear. Over 40 variations of artificial lures and flies were used. Fishing occurred each day from approximately 1000h to 2200h. Rainbow trout were landed as quickly as possible using soft knot-less nets, measured to the nearest mm (FL), and tagged with individually numbered Floy ® FD-67 T-Bar anchor tags. Tags were inserted at the base of the dorsal fin so the "T" anchor locked between the bases of adjacent dorsal fin rays. Tagged fish also received an adipose fin-clip as a secondary mark to permit subsequent evaluation of tag loss. Fish less than 250 mm in length were released without being tagged. Capture locations were recorded using GPS coordinates. All fish were released in the immediate vicinity of their capture location. Rainbow trout that were bleeding, lethargic, or otherwise appeared to be in poor health were not tagged. The presence of tag loss was evaluated during the recapture event by examining each fish for the presence of primary and secondary marks.

Abundance Estimation

To minimize the number of parameters estimated and the variance of abundance estimates, we planned to estimate abundance using a two-event, closed-population, mark-recapture estimator (Seber 1982). Unmarked fish caught during the recapture event were not marked, so unique captures of individual unmarked fish could not be identified. For that reason, the Bailey sampling-with-replacement estimator (Seber 1982) was tentatively selected.

The assumptions of a two-event, closed-population, mark-recapture experiment are:

1. the population is closed, i.e., there is no mortality or recruitment between the marking and recapture events;
2. marked fish completely mix with unmarked fish between the marking and recapture events;
3. all fish have an equal capture probability in either the marking or recapture event;
4. marking does not affect capture probabilities in the recapture event;
5. marks are not lost between events; and
6. all marks are correctly identified in the recapture event.

Note that these assumptions are not mutually exclusive, and it is not necessary for all to be satisfied in order to obtain unbiased estimates of abundance (Seber 1982). A series of statistical tests was used to evaluate the degree to which these assumptions were satisfied and, if necessary, guide the selection of an alternative estimator.

Diagnostic Statistical Tests

The assumption of population closure (Assumption 1) is not testable. Because the events were relatively close together in time and occurred after spawning, substantial immigration or emigration was not expected. An unknown number of fish were undoubtedly harvested between the events, but the harvest rate is thought to have been small. Seber (1982) provides a summary of the effect of various violations of the closure assumption. Potential violations of this assumption were not thought to be consequential in this case.

The assumption of complete mixing of marked and unmarked fish is not testable. However, spatial mixing within the study area can be evaluated. The movement of fish within the drainage was assessed by plotting capture and recapture locations of tagged and recaptured fish. Paired Smirnov tests (Conover 1999) were used to detect the presence of spatial selectivity of captures in the marking and recapture events, which would require spatial stratification (e.g., Darroch 1961). The first Smirnov test (Test 1) is of the equality of the distributions of capture location of marked fish in the marking and recapture events; if these distributions are significantly different, the recapture event was spatially selective. The second Smirnov test (Test 2) is of the equality of the distributions of capture locations of all fish captured in the marking and recapture events. The combined results of both tests provide information on whether the marking event was spatially selective (Table 1). The tests were conducted such that the experiment-wide error rate of both tests was no greater than = 0.05 (Sokal and Rohlf 1981).

The hypothesis that all fish have equal capture probabilities (Assumption 3) cannot be tested completely. As with Assumption 2, paired Smirnov tests (Conover 1999) of the equality of length distributions were used to detect the presence of size-selectivity in the two capture events. The presence of size selectivity would necessitate the use of a size-stratified abundance estimator. The size distribution of fish captured during one event had to be adjusted to account for growth between the events prior to conducting the Smirnov tests. Because the time between events was relatively short, growth was expected to be slight and length at the time of recapture was expected to be linearly related to length at the time of the marking event. Length was measured with error in both events, so a linear measurement-error model (Fuller 1987) was fit to the paired length data of fish whose lengths were measured in both events. Because fish were measured under similar conditions in both events, the ratio of measurement variances was assumed to equal 1.0. The lengths of unmarked fish in the recapture event were standardized to the time of the marking event using the estimated linear relationship prior to conducting the Smirnov tests. The results of the Smirnov tests were interpreted as summarized in Table 1.

TABLE 1.–Interpretation of paired Smirnov tests for detection of selectivity.

Smirnov test results		Conclusion	
Test1	Test 2	Marking event	Recapture event
Significant	Significant	Inconclusive	Selective
Significant	Not significant	Selective	Selective
Not significant	Significant	Selective	Not selective
Not significant	Not significant	Not selective	Not selective

Smirnov tests were conducted using Monte Carlo simulation (Manly 1990) to avoid potential inaccuracies of asymptotic approximations of the test significance (p-value). For each Smirnov test, the two sample empirical distribution functions (EDF), one for each event, were constructed. The test statistic was the maximum difference between the two EDFs. The data from both events were then pooled to estimate a single distribution function under the hypothesis of equality. Two random samples, of sizes equal to those observed in the two events, were drawn with replacement from the pooled EDF. The maximum difference between the EDFs of the two simulated samples was computed and compared to the value of the test statistic. This process was repeated 10,000 times for each test. The collection of simulated maximum differences in the EDFs provides an estimate of the distribution of the test statistic under the hypothesis of equality. The proportion of those values exceeding the observed value of the test statistic provides an estimate of the p-value of the test. The standard error of the p-value was estimated using the usual binomial estimator (e.g., Cochran 1977).

The Monte Carlo simulation test was implemented in a computer program written in the FORTRAN programming language and compiled using version 6.1 of the Professional Edition of the Compaq Visual FORTRAN compiler (Compaq 1999). Random numbers were generated using a modification of the "RAN1" function of Press et al. (1988). The program's user interface was developed using the RealWin software library (Indowsway Software, http://www.indowsway.com).

The validity of the assumption that marks are not lost between events (Assumption 5) was assessed by carefully examining each fish for both primary and secondary marks. Assumptions 4 and 6 are not testable in a two-event mark-recapture experiment.

Results

Biological Data

The mark-recapture experiment encompassed a total of 43 days, with a hiatus of 17 days between the marking and recapture events. A total of 1,226 unique fish were handled during the marking event. The first tagging crew tagged and released 203 rainbow trout. The second tagging crew tagged and released 914 previously unmarked rainbow trout. In addition, the second crew recaptured 19 fish tagged by the first crew and three fish they had tagged. Two fish recaptured by the second tagging crew were seriously injured while being recaptured and were removed from the pool of tagged fish. The 1,115 unique and apparently healthy fish tagged by the two crews were pooled into a single group of tagged fish for the estimation of abundance. An additional 109 fish were captured and released without tags during the marking event, including 42 fish (3.4%) that were killed and 16 fish (1.3%) that were bleeding from a gill arch.

During the recapture event, 1,146 rainbow trout were captured and examined for tags and secondary marks. A total of 103 fish, 16 tagged by the first crew and 87 tagged by the second tagging crew, were found to have marks. One fish was found to have a secondary mark but no tag; however, its dorsal fin had sustained a substantial injury thought to have caused the tag loss. We therefore concluded that, in effect, tag loss did not occur during the relatively short period over which the study was conducted. Eleven rainbow trout were killed (1.0%) and 18 (1.6%) were bleeding from a gill arch during the recapture event.

The investigation plan specified that fish less than 250 mm in length would not be tagged. Thirty-three fish with lengths less than 250 mm were captured during the marking event, and three were tagged. During the marking event, the smallest and largest tagged fish had lengths of 220 and 577 mm, respectively (Table 2). The smallest and largest fish captured during the recapture event had lengths of 122 and 615 mm, respectively. Of the tagged fish captured during the recapture event, the smallest and largest fish were 258 mm and 544 mm.

Paired length measurements were obtained from 98 fish that were tagged, recaptured, and measured in both events. Data from two fish were excluded as outliers because the apparent extreme growths of 95 mm and 104 mm were considered recording errors. A linear measurement-error model (Fuller 1987) was fit to data on the remaining 96 fish to account for growth between the mark and recapture events. The model fit the data quite well ($R^2 = 0.94$), and there was no sign of non-linearity in the relationship (Figure 2). The results (Table 3) indicate that fish grew slightly over the course of the experiment, with small fish growing somewhat more than large fish.

TABLE 2.–Extreme lengths (mm) observed during the mark-recapture experiment. Standardized lengths are the lengths at the time of the marking event, which were measured for marked fish and estimated for unmarked fish.

	Measured length (mm)		Standardized length (mm)	
Event	Minimum	Maximum	Minimum	Maximum
Marking	220	577	-	-
Recapture – marked	258	544	258	532
Recapture – unmarked	122	615	106	614

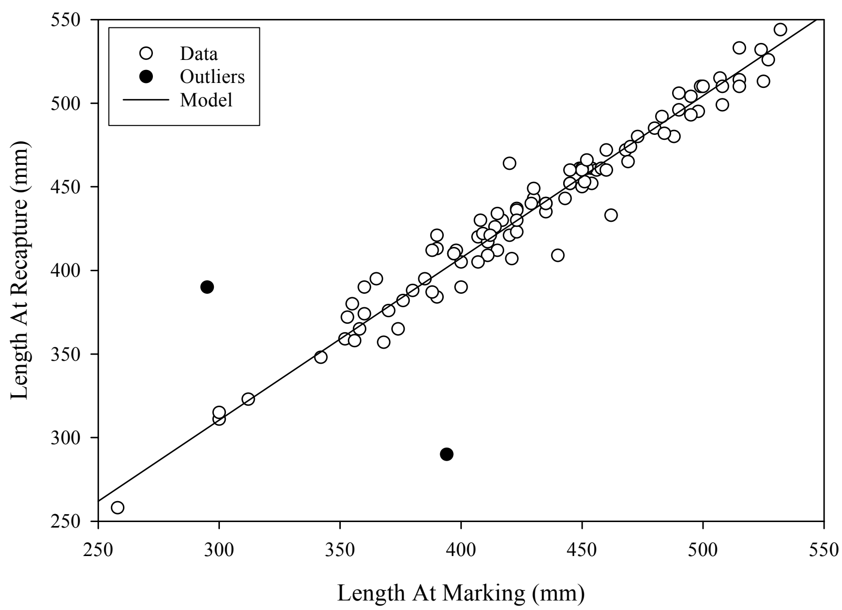

FIGURE 2.–Linear growth model and paired length data used to estimate model parameters. Filled circles indicate data that were excluded prior to fitting the model.

TABLE 3.–Linear growth model parameter estimates and standard errors.

Parameter	Estimate	Standard error
Intercept	19.596	8.8616
Slope	0.970	0.0205

The estimated model

$$L_r \quad = \quad 19.596 + 0.970 L_m$$

where

Lm = length at time of marking and

Lr = length at time of recapture,

was used to standardize lengths of unmarked fish captured during the recapture event to the time of the marking event (Table 2) prior to conducting Smirnov tests for the equality of length distributions.

Diagnostic Statistical Tests

Paired data on the capture and recapture locations of 103 fish were obtained. Two fish had location information that was extreme in comparison to other fish tagged during the same days; those data were assumed erroneous and were deleted. A plot of the remaining data (Figure 3) indicated that large movements of fish within the study area were not common.

Paired Smirnov tests of the equality of the distributions of capture locations did not indicate the presence of spatial selectivity. For the first test, the locations of 1,114 marked fish were available from the marking event, while the locations of 102 marked fish were available from the recapture event; one recaptured fish was missing location information. The first test did not detect significant spatial selectivity, with p = 0.8002 and s.e.(p) = 0.0040 (Figure 4). In the second test, the locations of 1,223 and 1,145 fish were available from the marking and recapture events, respectively. The second test also did not detect significant spatial selectivity, with p = 0.0619 and s.e. (p) = 0.0024 (Figure 5).

Paired Smirnov tests of the equality of length distributions suggest that size-based selectivity did occur. For the first test, lengths of 1,111 and 101 fish were available from the marking and recapture events, respectively. The test did not detect significant differences in length distribution, with p = 0.1449 and s.e. (p) = 0.0035 (Figure 6), however, note the seemingly reduced recapture rate of small fish. For the second test, lengths of 1,219 fish were available from the marking event, while lengths of 1,136 fish were available from the recapture event. The second test did detect a significant difference in length distributions, with none of the 10,000 simulated values of the test statistic exceeding the observed value (Figure 7; p < 0.0001, s.e.(p) < 0.0001). The interpretation of these results (Table 1) is that the recapture event was not size-selective, but that the marking event was, in effect, preferentially selecting larger fish.

Because the recapture event was apparently not size-selective, the standard analysis is to use an unstratified estimator. However, characteristics of the length distributions suggest that such an analysis might lead to over-estimation of abundance. Very few of the marked fish under 350 mm were recaptured. While nearly 10% of the tagged fish were less than 300 mm (Figure 6), only one of those fish was recaptured. The recapture rate increases slightly between 300 and 350 mm, with 4 fish in that size range being recaptured. The size distributions of marked fish with length 350 mm or greater in the two events appear very similar. Conversely, a relatively large number of small-unmarked fish were captured (Figure 7). As with the marked fish, the size distributions of all fish captured in the two events are quite different for fish less than 350 mm in length, but very similar for larger fish. In summary, the recapture event caught a relatively large number of small fish, but small marked fish appear to be under-represented relative to the numbers tagged and released.

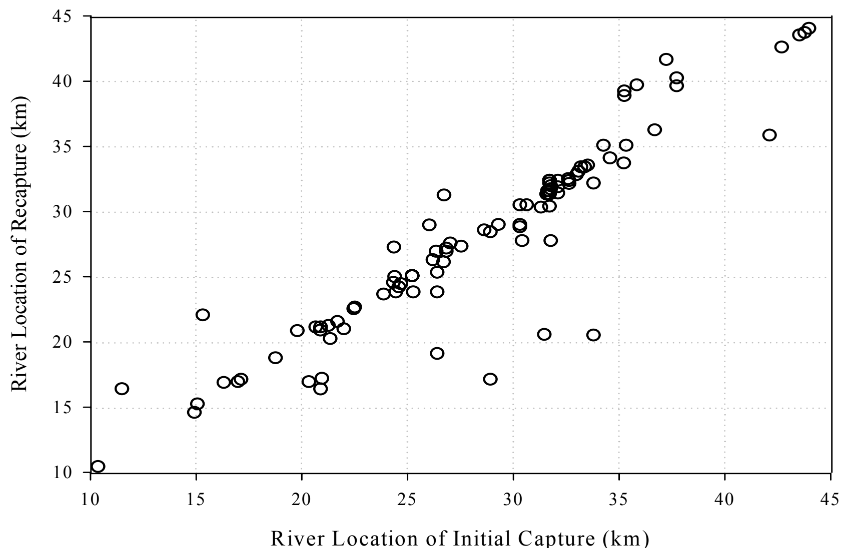

FIGURE 3.–Paired locations of marking and recapture showing movement of tagged fish within the study area.

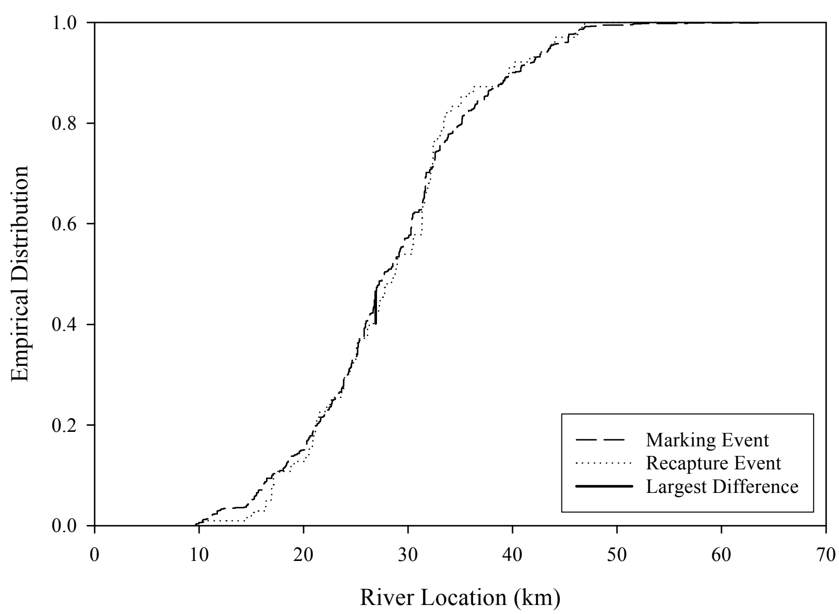

FIGURE 4.–Empirical distributions of the capture locations of marked fish in the marking and recapture events (Test 1).

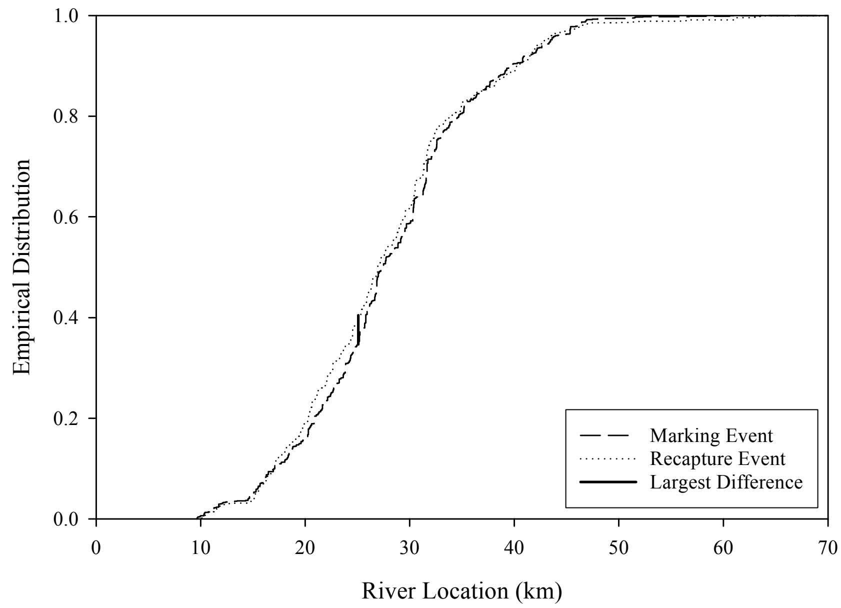

FIGURE 5.–Empirical distributions of the capture locations of all fish captured in the marking and recapture events (Test 2).

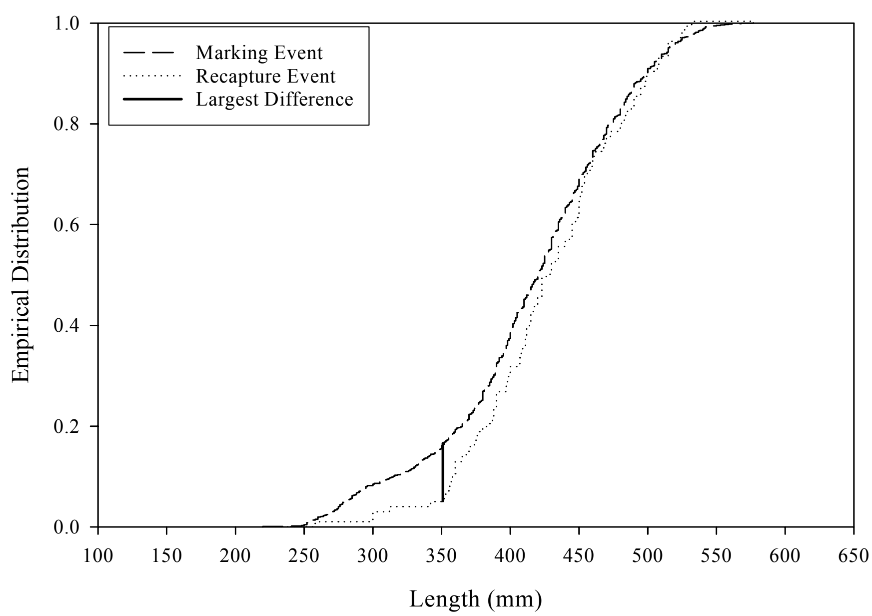

FIGURE 6.–Empirical distributions of the lengths of marked fish in the marking and recapture events (Test 1).

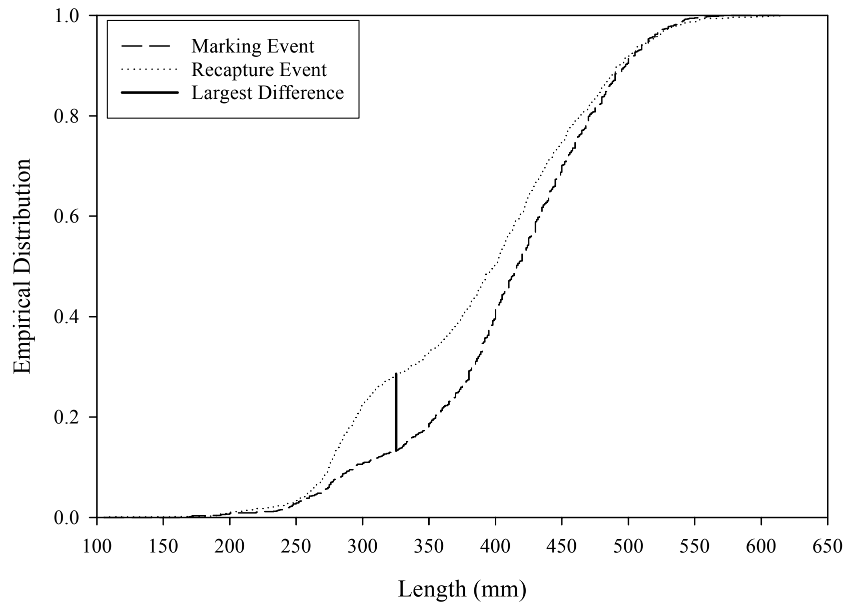

FIGURE 7.–Empirical distributions of the lengths of all fish captured in the marking and recapture events (Test 2).

The low recapture rate of small marked fish (Figure 6) was evaluated by computing the recapture rate within 50 mm length bins. The proportions, along with normal-approximation 95% confidence intervals, are plotted versus length bin in Figure 8. Marked fish less than 350 mm clearly had a reduced probability of recapture.

To reduce bias that could be caused by the apparent unavailability of small marked fish in the recapture event, a length-stratified estimator was employed. Abundance estimation was limited to fish of at least 300 mm in length; fish less than 300 mm in length were excluded from the analysis. Two strata were employed, one consisting of fish less than 350 mm in length and the second consisting of fish at least 350 mm in length. The lengths of unmarked fish captured in the recapture event were adjusted to account for growth prior to establishing stratum membership using Equation (1).

Because of the broad size range of the second stratum, the Smirnov tests were repeated for fish in the larger size stratum. For the first test, 939 and 96 marked fish with lengths of at least 350 mm were available from the marking and recapture events, respectively. The test did not detect significant differences in lengths, with $p = 0.9916$ and s.e. $(p) = 0.0009$ (Figure 9). For the second test, length data from 999 and 764 fish were available from the marking and recapture events, respectively. The second test did not detect significant differences in lengths, with $p = 0.8291$ and s.e.$(p) = 0.0038$ (Figure 10).

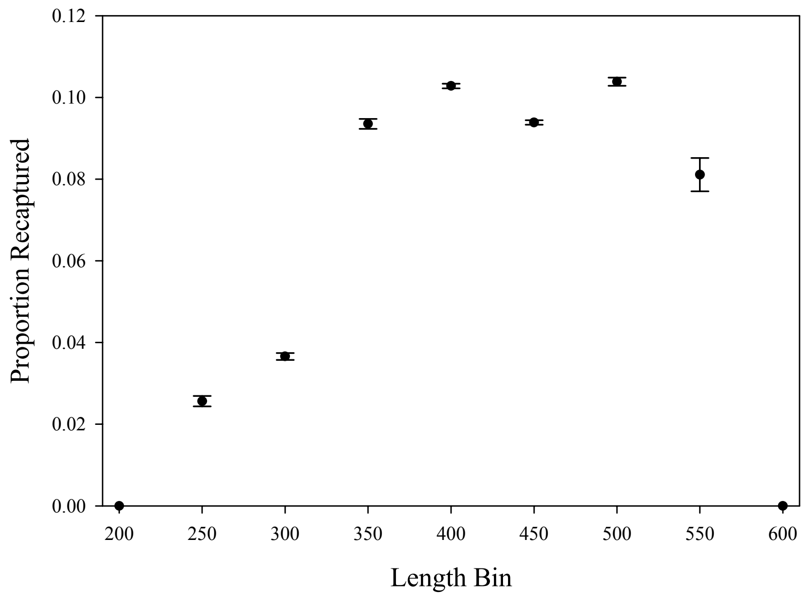

FIGURE 8.–Proportion of marked fish recaptured in the recapture event, with 95% confidence limits, by length bin.

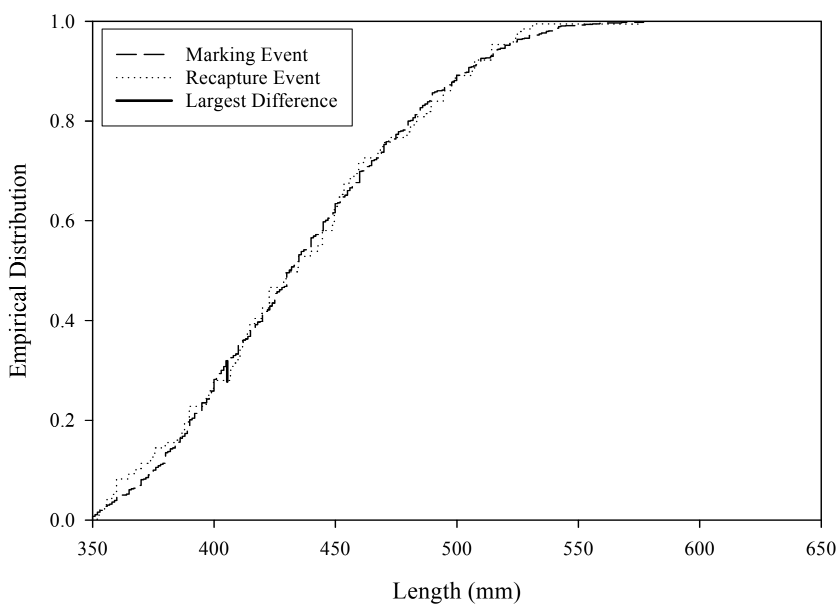

FIGURE 9.–Empirical length distribution of marked fish with lengths of at least 350 mm in the marking and recapture events (Test 1).

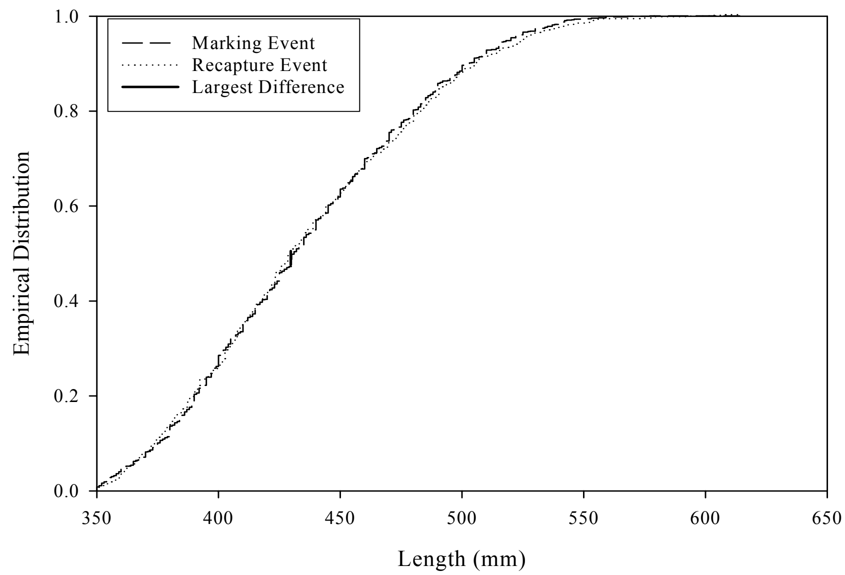

FIGURE 10.–Empirical distribution of the lengths of all fish with lengths of at least 350 mm in the marking and recapture events (Test 2).

Abundance Estimation

Missing data from a small number of fish complicated the determination of capture histories and stratum membership. Four fish tagged in the marking event had missing length data. These fish were apportioned to length strata using the proportions of all fish tagged in the marking event whose stratum membership was known (Table 4). Eight fish in the recapture event had missing length data. Similarly, these fish were apportioned to length strata using the stratum proportions of all fish in the recapture event whose stratum membership was known. In addition, two fish in the recapture event were recaptured fish, but their tag number was unknown. Of all tagged fish captured in the recapture event, 77.53% were tagged as a part of the mark-recapture experiment. This proportion was used to apportion the two fish to the marking event. In all cases, the fish in these three categories of missing data were apportioned using the exact proportions, resulting in non-integer frequencies of capture histories.

TABLE 4.–Stratum membership proportions used to apportion fish with missing length data among length strata.

Length stratum (mm)	Marking event	Recapture event
$L < 300$	0.0819	0.2236
$300 \le L < 350$	0.0729	0.1039
$L \ge 350$	0.8452	0.6725

Stratum summary statistics and estimates of abundance are presented in Table 5. Note that fractional numbers of fish result from the methods used to approximate missing data. The abundance of fish less than 350 mm in length was estimated to be 1,873, with standard error 735, while the abundance of fish with length 350 mm or larger was estimated to be 7,390, with standard error 693. Pooling strata, the abundance of all fish of length at least 300 mm was estimated to be 9,263, with standard error 1,010.

TABLE 5.–Stratum summary statistics and estimates of abundance and measures of variability.

Length stratum (mm)	Marks released	Recapture event: Fish captured	Recapture event: Marks recaptured	Abundance estimate	Standard error	Coefficient of variation
300 ≤ L < 350	81.292	119.000	4.209	1,873	735	39.3%
L ≥ 350	942.381	770.182	97.342	7,390	693	9.4%
Pooled				9,263	1,010	10.9%

Length Composition

The Smirnov tests indicated that neither event was size-selective for fish 350 mm or larger in length. For that reason, the length composition of that component of the population was estimated by pooling fish captured in both capture events. The length composition of fish from 300 mm to 350 mm in length was estimated from fish captured in the recapture event, consistent with the differences in the length distributions in the two events. Lengths observed in the recapture event were standardized to the time of the marking event. These two estimates of length composition were weighted by the estimated stratum abundance (Table 5) and pooled to estimate the length composition of the population with length 300 mm or greater (Figure 11).

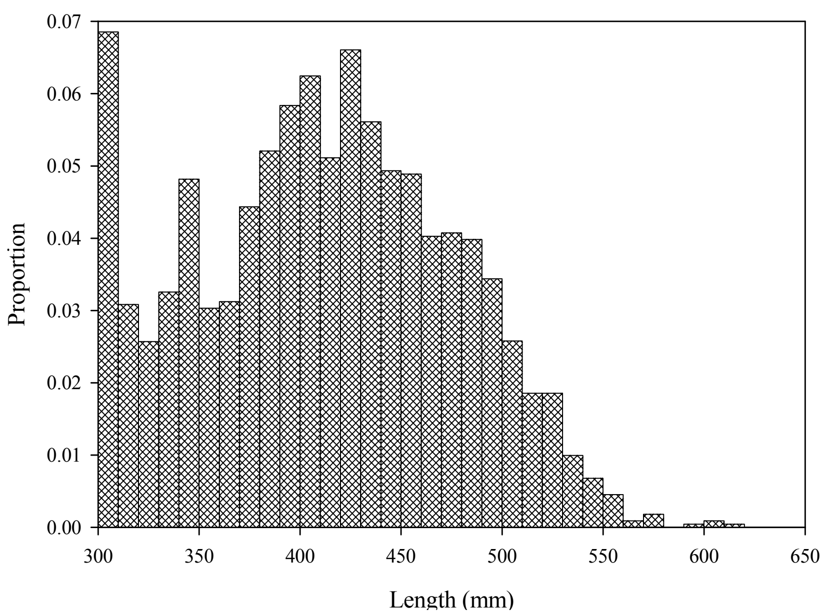

FIGURE 11.–Estimated length composition of fish greater than 300 mm in length.

Discussion

We were able to develop a length-stratified estimate of rainbow trout abundance within a 70 km section of the Kisaralik River during 1997. Statistical characteristics of the estimates differ between the strata. The estimate for the larger size stratum, consisting of fish with lengths 350 mm and larger, are precise (Table 4) and are thought to be essentially unbiased. A relatively large number of fish were handled in both the marking and recapture events, and the similarity of the length distributions (Figure 9, Figure 10) increases confidence in the estimate. An unknown number of fish were probably harvested between the events, but the harvest rate is thought to have been small based upon the low number (<5) of other anglers encountered on the river. This estimate is therefore of the quality needed for use in making management decisions.

The estimate for the smaller size stratum, fish from 300 mm to less than 350 mm in length, is less reliable. In addition to the potential for assumptions to have been violated, fewer fish were marked in this size stratum and the recapture rate was approximately 50% that of the larger size stratum, with approximately four fish being recaptured (Table 5). The relatively large coefficient of variation reflects the effect of the small sample sizes. The differences in the length distributions in the marking and recapture events (Figure 6, Figure 7) provide an additional reason for viewing this estimate with caution. The abundance estimate for the smaller size stratum should not be used to make consequential management decisions. However, the imprecision and potential bias of the abundance estimate for the small size stratum should not be viewed as a serious deficiency of the study. Most management decisions for Kisaralik River rainbow trout will involve the sport fishery, which preferentially targets larger fish. For those reasons, having an abundance estimate for larger fish with high statistical quality is a priority and will satisfy most needs of fishery managers.

Missing data were approximated using proportions from fish having complete information. This method is a source of additional variability that is not incorporated into estimates of precision, but should not introduce estimation bias. The number of fish with missing data was small, and the variability not accounted for is thought to be small and inconsequential from a practical perspective.

The results of the paired Smirnov tests of the equality of length distributions (Figures 6 and 7) indicate that one or more model assumptions were violated. The joint interpretation of the test results leads to the conclusion that the marking event was size selective, while the recapture event was unbiased. However, even though the first Smirnov test (Figure 6) was not statistically significant, there is evidence that small marked fish had a reduced capture probability in the recapture event (Figure 8). A substantial number of fish smaller than 350 mm were tagged, but few were recaptured, even though unmarked fish of this size were relatively abundant in the recapture event (Figure 7). The cause of these differences in the length distributions is unknown, but there are several possible explanations. Given that similar capture methods were used during both capture events, a cause for selective sampling in the marking event is not readily apparent, though it certainly could have occurred. Growth recruitment seems unlikely, as fish observed in both capture events displayed little growth (Figure 2) and the capture events were separated by less than 3 weeks. The immigration of small-unmarked fish into the study area would explain the increased capture of such fish during the recapture event. However, neither immigration or growth recruitment, nor selective sampling in the first capture event can explain the apparent tendency of small marked fish to have reduced recapture probabilities. Another possibility is that small marked fish suffered elevated mortality or displayed a behavioral response to capture and marking that decreased their availability during the recapture event. The investigation plan called for no marking of fish smaller than 250 mm because of concern that the marking process might cause increased mortality of small fish. If the concern was well founded, it may be that the effect was observed on fish larger than 250 mm. While it is impossible to determine which factors were responsible, some combination of reduced availability of small marked fish and immigration to the population seems most likely. Consequently, the abundance estimate for the small size class may be biased to an unknown degree. Fortunately, the cause does not appear to have affected larger fish and we have no reason to doubt the statistical quality of that estimate.

Movement of tagged rainbow trout within the study area was minimal, with most recaptures occurring within a few kilometers of the locations fish were tagged (Figure 3). Limited movement has the potential to cause variable capture probabilities throughout the study area and necessitate the use of a spatially stratified abundance estimator. Spatial stratification is undesirable because of the large number of parameters needed to model spatial movement (Darroch 1961) and the resulting increase in variability. However, the distributions of capture locations of both marked fish and all fish were very similar in both marking and recapture events (Figures 4 and 5), implying that efforts to distribute fishing effort in proportion to abundance were largely successful in avoiding the need to stratify spatially.

Under a conceptual model that true abundance is a monotonic decreasing function of size and that gear selectivity increases monotonically with size until reaching an asymptote, the mode of the length density indicates the length at which fish are fully recruited to the gear. In this study, the mode of the length density during the marking event was approximately 415 mm (Figure 11). However, this conceptual model is relatively simplistic and may not be applicable in this application. The similarity in length distributions (Figures 9 and 10) suggests that any gear selectivity that existed was consistent between marking and recapture events for fish as small as 350 mm, and fish of that size may be fully recruited to the gear. A gear selectivity study of rainbow trout using a weir to mark fish and angling gear to recapture fish found that angling gear was not size selective for fish larger than approximately 250 mm (Nick Hetrick, U.S. Fish and Wildlife Service, personal communication).

This study provides the first estimates of the abundance and size composition of Kisaralik River rainbow trout. The estimate for rainbow trout greater than 300 mm was 9,263, which corresponds to a density estimate of 130 fish per kilometer for the 70-rkm study section. Median and maximum sizes of the Kisaralik River population are similar to other populations in Alaska (Table 6). Such information is of general biological interest and provides important documentation of resources in the Yukon Delta National Wildlife Refuge. In addition, effective management of the population may depend heavily on these estimates, or similar estimates obtained using a replication of our methods, in the future.

In 1997, the abundance of larger fish appeared adequate, and the size composition similar to that observed in other populations of southwestern Alaska. Adams (1996), however, noted an absence of fish greater than 600 mm after surveying the Kanektok River in 1993, six years after Wagner (1991) completed a survey of the river in 1985-87. Wagner's population estimate for rainbow trout > 300 mm in a 32-rkm study section of the Kanektok River was 17,159 - 20,815. This equals a density of 536–631 fish/ km, almost four times greater than the 130 fish per kilometer estimate for the 70-rkm study in the Kisaralik River. Because the 70-kilometer section surveyed on the Kisaralik River included both prime and sub prime habitat, the number of fish per river kilometer will be lower when considering the entire surveyed section. Other river surveys have concentrated on smaller sections with densities of fish sufficient to generate a population estimate. The prime habitat in the Kisaralik River is believed to encompass an 11 km section. This was determined from compilation of captures of fish per rkm. Catches during the mark period in 11 of 69, 1-rkm sections, exceeded 68 fish per rkm. How this compares to that of the Kanektok River is unknown, and no core area population estimates were generated. By conducting our survey over most of the river, we were able to meet the assumptions necessary for a population estimate, and feel that it represented the majority of the river.

TABLE 6.–Length ranges, sampling effort, and population estimates of rainbow trout from the Kisaralik and other Western and South Central Alaska rivers.

River	Sample[1]	Kilometers Sampled	number/rkm >~300 mm	Mean Length	Median Length	Length Range
Kisaralik 1997 June-Aug.	2,902	70	130	408	417	122-615
Kisaralik 1997 July	1,320	70	No estimate	411	420	166-578
Kwethluk 1998[2]	1,374		No estimate	395	395	164-525
Kanektok 1985-1987[3]	1,036	32	536-631	426	435	200-640
Kanektok 1993-94[4]	786	32	No estimate	434	450	181-581
Goodnews 1988-1989[5]	387	143+	No estimate	419		90-686
Goodnews 1993[6]	342	143+	No estimate	439	445	226-625
Goodnews 1994[6]	129	143+	No estimate	440	430	127-573
Kenai 1999[7]	841	12	453	~350		200-649
Kenai 1987[8]	299	13.7	102	~400		200-749
Willow Creek 1998[9]	549	11.2	223	327		173-650

1. Hook and Line samples.
2. Unpublished data, U.S. Fish and Wildlife Service
3. T. Wagner 1991
4. J. Adams 1996
5 Irvin, D.B. and M.A. Faustini 1994 (Includes North Fork, Middle Fork and Kukaktlik River sampling)
6 M.A.Faustini 1996
7 Larson, L. L. and P. Hansen 2000
8 Larson, L. L. and P. Hansen 2000
9 Bartlett L. D, and P. A. Hansen 2000

Other rivers in Alaska have shown a higher density of fish than that found in the Kisaralik River. For example, a survey in 1999 of a 12-km section of the Kenai River below Skilak Lake produced a population estimate of 5,445 fish greater than 300 mm in length, or 453/km (Larson and Hansen 2000). A stock assessment project of Willow Creek (a Susitna River tributary) estimated 3,880 rainbow trout age one and older in an 11.2-km section. Approximately 2,502 rainbow trout or 223 fish per kilometer were age three and older (Bartlett and Hansen 2000). Age three fish in this study averaged 317 mm in length. These comparisons of densities per river kilometer are not absolute but give a relative assessment of each river. Each river has different habitat characteristics, including holding water and over-wintering habitat. For example, the Kenai River rainbow trout populations utilize lakes as over-wintering habitat (Palmer 1998).

Sport fish use of Kisaralik River rainbow trout has increased in recent years. Floatplanes bringing in float anglers access Kisaralik Lake from Bethel, Dillingham, and Anchorage. With the advent of sportfishing services in Bethel, use will increase in the future. Regulations for sport fishing have changed from catch and release to that of a two fish limit with one over 500 mm. If use continues to build as expected, the harvest of rainbow trout, including some mortality from catch and release, will undoubtedly increase. Subsistence use of the resource is currently unknown, but residents of villages including Akiak and Bethel harvest resident fish including rainbow trout from the river. Information on the abundance and size composition of the population is necessary to manage the fisheries and achieve the Refuge management goals of conserving the population and providing subsistence opportunities for area residents.

Recommendations

The rainbow trout population in the Kisaralik River appeared to be healthy at the time of the survey. Catch and release regulations were in place on the river from 1998 through 2003. New sportfish regulations will allow for the harvest of two trout per day, with only one 500mm (20 inches) or greater in length. Because the Kisaralik River is readily accessible from the population hub of Bethel and surrounding villages, it will probably be the first to experience a reduction in abundance and possibly a shift in the length frequency. The Statewide Harvest Survey will not detect increased harvest by subsistence users and those not obtaining a sport fishing license. These anglers are not currently restricted to the same regulations as sport anglers. Therefore, regular evaluation of the rainbow trout population status on a six-year basis, to follow the Alaska Board of Fisheries meeting cycle, is recommended. If shifts are detected, conservative management may be necessary to maintain population stability. River float and powerboat use should be monitored on an annual basis to document any changes in traffic.

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